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BEFORE THE ENERGY SUBCOMMITTEE OF THE U.S. HOUSE OF REPRESENTATIVES'  
COMMITTEE ON SCIENCE

**HEARING ON "WHAT ARE THE ADMINISTRATION PRIORITIES FOR CLIMATE  
CHANGE TECHNOLOGY?"**

NOVEMBER 6, 2003

Chairman Biggert and members of the Energy Subcommittee, thank you for inviting me to comment on the subject of climate change technologies. You have asked me to address three issues:

- the attributes of a balanced climate change technology portfolio,
- the "no regrets" strategy of targeting cost-effective, energy-efficient measures, and
- the non-climate benefits of federal climate change R&D investments.

Many of my comments on these issues are drawn from a study completed in November 2000, called the *Scenarios for a Clean Energy Future*. This study, which I co-led, examined the ability of energy-efficient and clean energy technologies to reduce U.S. greenhouse gas emissions. It was commissioned by the U.S. Department of Energy (DOE), was co-funded by the U.S. Environmental Protection Agency, and was completed by researchers from five DOE national laboratories.<sup>1</sup> My comments draw on other research, as well, including *Technology Opportunities to Reduce U.S. Greenhouse Gas Emission* (a.k.a. the "11-Lab Study")<sup>2</sup> and a recent workshop on *Basic Research Needs to Assure a Secure Energy Future*.<sup>3</sup>

**Attributes of a Balanced Climate Change Technology Portfolio**

The balance of a climate change technology portfolio can be evaluated along many dimensions. These include market and technical risk; time-to-market introduction (near-, medium-, and long-term); size of potential greenhouse gas emissions reductions; magnitude and nature of other benefits; R&D investment requirements and other costs; and distributional impacts (by region, income group, etc.). For carbon dioxide, the most important of the greenhouse gases, the RD&D portfolio for climate change should also consider the full spectrum of ways that carbon concentrations in the atmosphere can be reduced. These include:

- reducing the "energy intensity" of the economy (that is, total energy use divided by the gross domestic product),
- reducing the "carbon intensity" of the energy system (that is, carbon emissions per unit of energy consumed), and
- removing atmospheric carbon through "sequestration."

These three approaches embody distinct technology pathways to reduce greenhouse gas emissions. Energy intensity can be decreased through the more efficient use of fossil fuels in transportation,

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<sup>1</sup> The report can be found at [http://www.ornl.gov/ORNL/Energy\\_Eff/CEF.html](http://www.ornl.gov/ORNL/Energy_Eff/CEF.html)

<sup>2</sup> The report can be found at [http://www.ornl.gov/climate\\_change](http://www.ornl.gov/climate_change)

<sup>3</sup> The report can be found at <http://www.sc.doe.gov/production/bes/BESAC/reports.html>

buildings and industry and through system designs such as co-locating facilities that produce both electrical power and heat with facilities that need them. Carbon intensity can be decreased by increasing the efficiency of energy production, or by using either fuels that emit less carbon or technologies that use lower carbon-emitting fuels such as nuclear power plants and renewable energy sources such as hydroelectric, wind, and solar power plants. Ways to increase carbon sequestration include capturing and storing CO<sub>2</sub> after combustion but before it enters the atmosphere, and increasing the rate at which oceans, forests, and soils absorb CO<sub>2</sub> from the atmosphere.

To reduce carbon emissions significantly while sustaining economic growth, all three of these technology avenues may be needed. The 11-Lab Study concluded that these three approaches have different time dimensions. The report concluded that:

- In the first decade of this century significant advances in energy efficiency technologies could deliver substantial near-term carbon-reducing impacts by decreasing the energy intensity of the U.S. economy.
- Along with continued improvements in energy efficiency, research-based advances in clean energy technologies could reduce significantly the carbon intensity of the U.S. energy economy during the second decade. A wide range of improved renewable, fossil, and nuclear technologies could be introduced and widely deployed in this period.
- Complementing ongoing advances in efficiency and clean energy technologies well into the third decade, carbon sequestration technologies could add a third important dimension to the package of solutions. Success in this technology area could enable the nation to continue its extensive use of fossil fuels without harming the global climate.

### **The "No Regrets" Strategy of Targeting Cost-Effective, Energy-Efficient Measures**

Like many other analyses, the *Scenarios for a Clean Energy Future* study described a large reservoir of highly cost-effective energy-efficient technologies that are available for deployment. Climate change strategies that focus on these technologies have been called “no regrets” approaches because they promote technologies that would be good for consumers and the economy irrespective of their climate change benefits. The fact that such technologies remain under exploited leads to two key questions. If energy-efficient technology is cost-effective, why isn’t more of it being used? If individuals and businesses can make money from energy efficiency, why don’t they just do it?

Although some like to assert that markets are perfect, practical experience tells us otherwise. Energy markets, like all markets, are plagued by imperfections that can impede the adoption of new products, even those that are beneficial and economical. These market failures include:

- Misplaced incentives (for instance, these often occur in apartment buildings where landlords pay the utility bills, giving tenants no incentive to conserve)
- Distorting fiscal and regulatory policies (for example, electricity rates that do not reflect the real-time cost of electricity production)
- Unpriced costs (such as the health problems associated with burning hydrocarbons)
- Unpriced benefits (such as the public benefits associated with energy R&D: because the benefits of private-sector investments in R&D extend beyond any individual firm, investments are insufficient from a public perspective).

The existence of market failures that inhibit investment in improved energy technologies is a primary driver for public policy intervention. In many cases, feasible, low-cost policies and programs can be put in place to eliminate or compensate for market imperfections, enabling markets to operate more efficiently for the benefit of society.

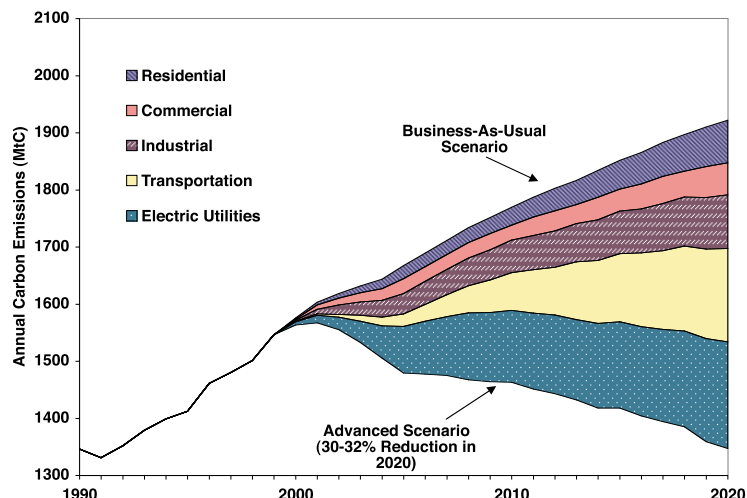
As one example, consider DOE's Best Practices Program, which has developed plant assessment and analysis tools and has conducted plant-wide assessments of energy-saving opportunities. The goal is to address key information barriers to the adoption of energy-efficient measures. Improvements to industrial utility systems (steam, compressed air, motors, and pumps, etc.) offer tremendous energy-saving opportunities. Industrial motor systems, for example, use 25% of all the electricity consumed in the United States. In just 5 of the program's initial industrial assessment projects, annual energy savings of \$17 million were realized, with an average payback on investment of 1.2 years. Altogether, the 28 assessments conducted to date have identified aggregate savings of \$163 million (390,000 MWh/yr of electricity and 10 trillion Btu/yr of natural gas). Full implementation of such energy-efficient technologies could save 10 to 20% of the power used in motor-driven industrial systems, saving billions of dollars annually.

The *Scenarios for a Clean Energy Future* study concludes that accelerating the development and deployment of energy-efficient technologies could significantly reduce air pollution and greenhouse gas emissions, oil dependence, and economic inefficiencies, at no net cost to the economy. The overall economic benefits of the technologies and policies that are modeled result in energy savings that equal or exceed the cost of implementing the policies and of investing in the technologies.

The results of two scenarios modeled in the *Scenarios for a Clean Energy Future* illustrate the magnitude of benefits that could arise from a "no regrets" approach:

- The business-as-usual (BAU) scenario assumes that current energy policies and programs continue, resulting in a steady but modest pace of technological progress and improved efficiencies.
- The advanced scenario is defined by an array of policies including a 50% increase in cost-shared federal energy R&D; expanded voluntary programs; tax credits for efficient appliances, vehicles, and non-hydro renewable electricity; voluntary agreements to promote energy efficiency in vehicles and industrial processes; appliance efficiency standards; renewable portfolio standards; and a domestic carbon cap and trading system.

The BAU scenario forecasts that U.S. energy consumption will increase from nearly 100 quadrillion Btu (quads) in 2000 to 119 quads in 2020. Carbon dioxide emissions are forecast to increase at a comparable rate, from 1,346 MtC in 1990 to 1,920 MtC in 2020 (see Figure 1).



**Figure 1. Carbon emission reductions, by end-use sector, in the advanced scenario.**

Under the advanced scenario, the United States consumes 23 quads (20%) less energy in 2020 than is predicted under the BAU forecast. Under the advanced scenario, U.S. CO<sub>2</sub> emissions drop in 2020 to 1,330 MtC (31%), avoiding nearly 600 MtC compared with the BAU forecast. Two-thirds of these reductions are due to “no regrets” energy efficiency improvements – improvements that shave \$120 billion off the U.S. energy bill in 2020. Consistent with the 11-Lab Study, energy intensity reductions occur quickly through energy efficiency investments. Carbon intensity reductions are also significant by 2020, and carbon sequestration technologies are assumed to take hold in subsequent decades.

### **Evidence that Climate Change R&D Investments Can Deliver Viable Technology Options**

What evidence do we have that climate change technology R&D can deliver products that consumers, industry, and businesses will choose to use? Consider the results of a recent study completed in 2001 by the National Academies as reported in *Energy Research at DOE, Was it Worth It?* This study concluded that energy efficiency and fossil energy research at DOE has produced economic net benefits:

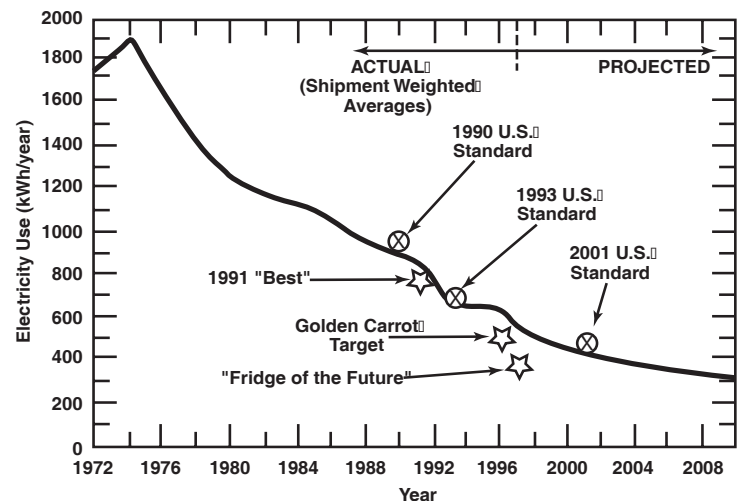
- Total net realized economic benefits associated with selected energy efficiency programs were approximately \$30 billion, substantially exceeding the roughly \$7 billion in total energy efficiency RD&D investment.
- The realized economic benefits of \$7.4 billion resulting from fossil energy programs instituted from 1986 to 2000, exceeded the estimated \$4.5 billion cost of the programs during that period.

The National Academies also noted that additional environmental and security benefits resulted, and there were significant options and knowledge benefits.

As one example of the many successes enumerated by the National Academies, consider the outcome of a major R&D effort that began in the late 1970s to improve the efficiency of household refrigerators.

Between 1977 and 1982, DOE invested approximately \$1.6 million in R&D to make home refrigerators more energy efficient. Working in a public/private partnership with compressor and appliance manufacturers, DOE and two federal laboratories identified ways of improving the performance of refrigerator compressors, motors, insulation, and controls, and they provided test data for use in the setting of national standards.

These technology investments, in conjunction with the issuance of appliance standards, cut the energy use of the average new refrigerator in half by the year 1990 and saved U.S. consumers \$7 billion in energy costs from 1981 to 1990 (1999 dollars) (see Figure 2).



**Figure 2. Average electricity use of household refrigerator/freezers by year of purchase.**

In 1997, a DOE–industry cooperative R&D effort developed a prototype “fridge of the future” that, again, used nearly 50% less energy than refrigerators then on the market and surpassed the 2001 efficiency standard for refrigerators. These developments, in combination with the 2001 U.S. standard, will save consumers billions of dollars in the future.

### **The Non-Climate Benefits of Federal Climate Change R&D Investments**

The National Academies also note in their 2001 study (*Energy Research at DOE, Was it Worth It?*) that environmental and security benefits have resulted from DOE’s energy efficiency and fossil energy research. These include cleaner air and water, which can produce significant public health benefits, and the potential for greater fuel flexibility, which is important to national security. In addition, the National Academies cite the importance of options and knowledge benefits. Options benefits are derived from technologies that are fully developed but for which economic and policy conditions are not currently favorable for commercialization. Knowledge benefits refer to the contribution of R&D to the stock of engineering and scientific information and wisdom.

Productivity improvements, product quality gains, and job creation have been important additional collateral benefits of many energy efficiency investments. These have been particularly significant in the industrial sector, where energy efficiency investments have led to greater labor productivity, better products through improved process control, greater equipment longevity, and waste minimization. Such productivity benefits often exceed the value of the energy saved from the introduction of advanced efficiency technologies in industry. Consideration of non-climate costs and benefits is important in the design of a climate change technology portfolio, because they have a significant impact on the likelihood of market success and the ultimate delivery of climate benefits.

### **Promising Energy Efficiency Technology Opportunities**

The nation has at its disposal an underutilized reservoir of currently cost-effective, energy-efficient technologies that can deliver significant greenhouse gas reductions, if targeted, market-based policies are implemented. Other energy efficiency technologies are on the brink of cost-effectiveness, but need

performance enhancements and cost reductions to become viable.. Still other technologies require significant science-based improvements to achieve major technical breakthroughs necessary for technical and market viability.

The *Scenarios for a Clean Energy Future* Study describes a range of policy options for accelerating the deployment of market-ready technologies. It also describes many of the near-term technology opportunities that could have a significant impact by 2020, if their performance and cost profiles can be improved. The 2003 report by DOE's Basic Energy Sciences Advisory Committee (BESAC), *Basic Research Needs to Assure a Secure Energy Future*, describes a set of research directions that could deliver the more fundamental and necessary breakthroughs. These directions underscore the importance of a strong physical sciences investment to enable the technologies that provide long-term solutions. A sampling of these research directions are listed below:

- **Residential, Commercial, and Industrial Energy Consumption**
  - Sensors
  - Solid state lighting
  - Innovative materials for new energy technologies
  - Multilayer thin film materials and deposition processes
- **Transportation Energy Consumption**
  - Integrated quantitative knowledge base for joining of lightweight structural materials
  - Vehicular energy storage
  - Fundamental challenges in fuel cell stack materials
  - Integrated heterogeneous catalysis
  - Thermoelectric materials and energy conversion cycles for mobile applications
  - Complex systems science for sustainable transportation
- **Distributed Energy, Fuel Cells, and Hydrogen**
  - Advanced hydrogen synthesis
  - High-capacity hydrogen storage for distribute energy of the future
  - Novel membrane assemblies
  - Designed interfaces

Based on the BESAC report, it is clear that the technology “pipeline” for reducing the energy intensity of the economy can be kept full for several decades. The energy-efficiency “no regrets” approach is not a short-lived phenomenon. Rather, it can take the nation well into the current century with climate-friendly solutions that will allow the economy to continue to grow.

Consider some of the materials breakthroughs that are already advancing the performance of energy technologies. Nickel aluminide alloys, developed through a DOE–industry R&D partnership, are extraordinarily strong, hard, and heat-resistant. Delphi Automotive Systems in Saginaw, Michigan, recently celebrated the installation of trays made from this new bimetallic alloy, in its steel carburizing heat-treating furnaces. These trays are cutting energy use by 5 to 10% by making it feasible to operate furnaces at higher temperatures and with fewer shutdowns. New steels promise similar advantages in a wide range of other applications. Researchers at Oak Ridge National Laboratory and Caterpillar have developed a new stainless steel (CF8C-Plus) that is stronger and tougher at both high and low temperatures than standard steels without costing more. Not only the steel itself but also the method of producing it, termed “engineered microstructures,” are being hailed as revolutionary. Immediate applications planned for CF8C-Plus include turbocharger housings for heavy-duty diesel engines and industrial gas turbines, which will allow higher temperature operations, producing significant energy savings. Nanoscience materials research promises to produce a stream of future breakthroughs that will offer continuing improvements to energy technologies.

The BESAC report also enumerates promising research directions that would reduce greenhouse gas emissions through advances in nuclear energy and renewable energy resources, by reducing the carbon intensity of the energy system. To meet the long-term goal of stabilizing atmospheric concentration of carbon, breakthroughs in sequestration technologies are also required. Finally, improved technologies are needed for measuring and monitoring the quantities and fluxes of greenhouse gases in the Earth's atmosphere.

## **Conclusion**

Energy conservation does not have the rugged, romantic appeal of oil drilling or coal mining. It does not wow us with massive dams, dramatic cooling towers, or tall smokestacks. But energy conservation does make a tremendous amount of energy available, prevents pollution, and avoids the emission of greenhouse gases. In fact, over the past 25 years, energy efficiency has become the number one domestic source of energy available for use by U.S. consumers. Nearly a quarter of the energy we use today is energy that would have been lost to waste without the energy-efficiency technologies that have been developed and implemented since the Arab oil embargo of 1973-74. In the absence of these energy efficiency improvements, the nation's greenhouse gas emissions would be significantly greater.

An expanded climate change technology portfolio could significantly accelerate the development and deployment of cost-effective, efficient, clean energy technologies – technologies that are good for business, good for consumers, good for the economy, and good for the environment. To secure these benefits, the nation needs to move forward on three major fronts – on policies to address market imperfections, R&D to accelerate technology advancements, and programs to facilitate technology deployment.

Thank you for this opportunity to talk with you today. I would be happy to answer any questions.

## **Biographical Sketch**

Marilyn Brown is the Director of Oak Ridge National Laboratory's Energy Efficiency and Renewable Energy Program, a \$125 million/year program of research on advanced energy efficiency, electric reliability, and renewable energy technologies. During her 20 years at ORNL, she has researched the impacts of policies and programs aimed at accelerating the development and deployment of sustainable energy technologies. Prior to coming to Oak Ridge, she was a tenured Associate Professor in the Department of Geography at the University of Illinois, Urbana-Champaign. While on the faculty, she received two NSF grants and funding from other sources to support her research on the diffusion of energy innovations. She has a Ph.D. in geography from the Ohio State University, where she was a University Fellow; a Masters Degree in resource planning from the University of Massachusetts; and a BA in political science (with a minor in mathematics) from Rutgers University. She has authored more than 140 publications and has received awards for her research from the American Council for an Energy-Efficient Economy, the Association of American Geographers, the Technology Transfer Society, and the Association of Women in Science. A recent study that she co-led (*Scenarios for a Clean Energy Future*) is the most comprehensive assessment to date of the policy and technology opportunities available to the United States to meet its energy-related challenges. This study was the subject of a dedicated issue of *Energy Policy* and has played a significant role in international climate change debates. Dr. Brown serves on the boards of several energy, engineering, and environmental organizations and journals. She is also a member of the *National Commission on Energy Policy*.